A New Coronary Sinus Lead for Left Atrial Pacing and Low-Energy Atrial Defibrillation- A Case Report

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Summary

Integrating the various efficient and specific atrial therapy concepts remains a challenge in the further improvement of electrotherapy by dual-chamber implantable cardioverter/defibrillators (ICD). A new helix-shaped lead that was placed in the coronary sinus (CS) position is presented in this paper. Intraoperative investigations were performed during implantation of the dual-chamber ICD PHYLAX AV in 2 patients. Signal amplitudes, P-wave duration, pacing thresholds, and impedance were measured. Furthermore, biatrial pacing was examined using the new lead in combination with a right atrial lead. Finally, the delivery of an automatic atrial therapy sequence was studied. The threholds for left atrial pacing depended used on the electrode configuration and ranged from 0.8 - 1.5 V in patient 1 and 1.5 - 3.3 V in patient 2 (0.5 ms pulse duration), respectively. Biatrial pacing configurations led to a reduction in P-wave duration from 140 ms to 70 ms in patient 2. Termination of an induced atrial flutter episode by a low energy defibrillation shock of 2 J successfully demonstrated atrial therapy capabilities. No dislocation of the new lead occurred during shock therapy.The investigations revealed that the use of the introduced CS lead enables reduction of P-wave duration in biatrial pacing configurations and termination of atrial tachycardia by low-energy defibrillation.

Key Words

Dual chamber ICDs, coronary sinus lead, biatrial pacing, atrial defibrillation

Introduction

Dual-chamber implantable cardioverter/defibrillators (ICD) represent a milestone in the development of electrotherapy of the heart. These devices offer the potential to adapt electrotherapy in a more differentiated way to the patients' specific rhythm disturbances. Present ICD generations have already proven an ability to detect and terminate ventricular tachycardias (VT) with high efficacy [1][2]. However, new approaches are being developed with the aim to provide specific and efficient therapy also in the atrium. A new lead was designed for positioning in the coronary sinus (CS) to enable therapy delivery in form of antitachycardia pacing (ATP), as well as defibrillation, in the left atrium. This paper reports on intraoperative results gained in two patients where this new CS lead was applied for left atrial sensing/pacing, biatrial pacing in combination with a standard right atrial lead, and delivery of atrial defibrillation shocks.

Materials and Methods

Patient Data:
These case reports are based on two implantations of the dual-chamber ICD PHYLAX AV (BIOTRONIK). Patient 1 (63 years of age, male) suffered from fast monomorphic VT, reaching heart rates of typically 180 to 210 bpm. For this patient, coronary artery disease was documented. Additionally, ischemic heart disease has been diagnosed due to a myocardial infarction of the posterior wall 2 years prior to the ICD implantation. The left ventricular ejection fraction was determined to be 50%. Patient 2 was a 44-year-old male. No cardiac disease has been diagnosed. This patient showed no VT but idiopathic atrial fibrillation (AF) episodes. Therefore, the patient underwent a MAZE surgery. As a result, AF episodes no longer occurred, but the patient still suffered from left atrial flutter (Afl). Furthermore, prolonged P-wave duration has been observed, reaching 140 ms during sinus rhythm.

Device:
The PHYLAX AV is a multiprogrammable, dual-chamber ICD [3]. The devices implanted during these investigations additionally offer an active discrimination method to differentiate between supraventricular tachycardia (SVT) and VT in case of 1:1 retrograde conduction by analysis of premature ventricular extrastimulus (PVES) delivery [4]. The algorithm is based on the assumption that PVES applied by the ICD will be blocked by refractory tissue in case of an ongoing SVT due to antegrade conduction of the atrial pulses. Therefore, no variation in the corresponding P-P intervals should occur. In contrast, during a VT episode premature extrastimuli do have a good chance to infiltrate the atrium via retrograde propagation. Thus, the related P-P interval will be shortened, indicating a VT. In detail, 8 extrastimuli with decreasing coupling interval will be applied in total by the ICD. To organize the timing of PVES delivery, two programmable time parameters are provided: the first one characterizes the prematurity of the first PVES compared to the previously measured R-R intervals, while the second describes the variation of the coupling intervals. This special function is expected to refine the discrimination specificity in case of 1:1 retrograde conduction of ventricular impulses during an ongoing VT. In the PHYLAX AV, atrial therapy modules may also be switched on.

Electrode Configuration:
All implanted electrodes were fractal coated for enhanced sensing and defibrillation performance. All leads were manufactured by BIOTRONIK.

The new CS lead has a special design with a helix-shaped curvature for fixation in the CS position. It consists of a shock coil for defibrillation and two proximal pacing ring electrodes denoted distal ring (dr) and proximal ring (pr). This lead was used for biatrial pacing in combination with one of the standard right atrial leads, Synox SX 53-BP or Retrox RX 53-BP. For this, a Y-connector was employed to bring the right atrial (RA) tip in contact with one ring of the CS lead. As a result, biatrial pacing was performed between RA tip and CS ring (both anodes) versus the RA ring (cathode). The CS lead was used for acute measurements during the intraoperative procedure and for delivery of an atrial therapy sequence.

Patient 1 obtained the CS lead only temporarily for the period of the intraoperative investigations. Permanently, a Synox SX 53-BP lead was implanted for atrial sensing and pacing. In addition, a Kainox SL lead (tip, a proximal ring and 2 shock coils in the right ventricular and superior vena cava position) was implanted and designated for ventricular sensing/pacing and defibrillation. A sketch of the lead positioning is shown in figure 1.

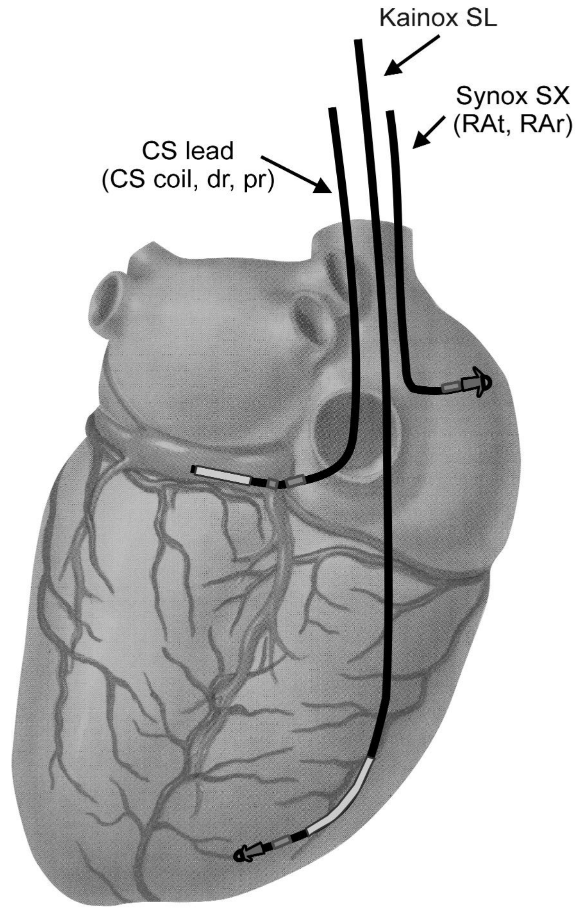

Figure 1. Scheme illustrating the position of the three different leads implanted in patient 1. The heart is displayed from the posterior view. The new coronary sinus lead (left), the right ventricular lead with its shock coils in the ventricular and vena cava superior position (middle) and the right atrial lead fixated at the lateral wall (right) are shown.

In patient 2, the CS lead was implanted chronically. Additionally, a J-shaped Retrox RX 53-BP bipolar lead was actively fixated in a lateral wall position of the right atrium and employed for atrial sensing and pacing. Patient 2 also received a Kainox SL lead.

Intraoperative Measurements:
During implantation, the following parameters for pacing/sensing and biatrial pacing were measured:

P- and R-wave amplitudes, P-wave duration, pacing thresholds, and impedance in both chambers.

Furthermore, the correct functioning of the algorithm for active discrimination was studied. These investigations were performed using an electrophysiologic study (EPS) catheter placed either in the right ventricle or in the CS position. Then a series of programmed stimuli was delivered by the catheter, leading to a constant heart rate of 122 bpm, which simulated either a VT with 1:1 retrograde conduction of the ventricular pulses or a SVT episode. The active discrimination capability of the ICD PHYLAX AV in this situation was documented.

Moreover, the response during delivery of automatic atrial therapy by means of ATP and low-energy shocks using the CS lead was investigated in patient 1. For this, a therapy sequence was programmed and tested for termination of an induced atrial flutter episode. This sequence consisted of 3 different modules: the first attempt was defined as a conventional ATP burst, which was repeated twice, then followed by a 50-Hz burst, and finally atrial shocks were programmed with increasing defibrillation energy. Antitachycardia pacing was delivered by the CS lead in the left atrium, and defibrillation shocks were released from the left atrial CS shock coil (connector: high voltage HV1) to the right atrial vena cava superior shock coil of the Kainox SL lead (HV2) and the active housing of the ICD. The course of this episode is illustrated in figure 2.

All intraoperative measurements were performed by employing either the external threshold analyzer ERA 300 or the TMS 1000 system (both by BIOTRONIK).

Results and Discussion

Table 1 and 2 summarize the measured pacing parameters of the 2 patients for the CS lead and the biatrial electrode configuration via the Y-connection, respectively. Particularly, left atrial pacing thresholds using the CS lead were measured and compared to the biatrial pacing configuration.

In both patients, measurements of the left atrial pacing thresholds revealed higher values than conventional right atrial pacing. Biatrial pacing in the described connection of the different right and left atrial electrodes also resulted in increased pacing thresholds. This effect can be explained by regarding the impedance for the right atrial and left atrial current path, respectively. Since the impedance between RA tip and RA ring is lower than that of the left atrial pathway (RA ring-CS ring), a favored current flow from RA tip to RA ring of the right atrial lead occurs, thus requiring an increased stimulation amplitude to ensure simultaneous left atrial capture.

On the other hand, attention has to be drawn to the fact that in this case report biatrial pacing significantly shortened the P-wave duration from about 140 ms for left atrial pacing to 70 ms (see table 2). A decreased P-wave duration is a goal of biatrial pacing, since it prevents interatrial conduction delays [5]. Thus, this result underlines that biatrial pacing in the used configuration with the new CS electrode works well.

After turning on the active discrimination algorithm, discrimination between SVT and VT in case of 1:1 retrograde conduction was investigated by overdrive stimulation. In patient 1, overdrive stimulation at 122 bpm in the coronary sinus position was correctly assessed as a SVT episode operating with the two introduced timing parameters at -150 ms and - 10 ms, respectively. This result was confirmed twice. When overdrive stimulation was applied in the right ventricle with 1:1 retrograde conduction into the atrium, the same parameter set resulted in successful classification of the VT and therefore in the correct kind of ventricular therapy delivery.

The next step entailed programming the above described atrial therapy sequence into the PHYLAX AV and examining its behavior concerning detection, classification and treatment of an induced atrial tachycardia (Afl). As was seen in figure 2, this episode was correctly detected by the ICD. The ongoing episode was treated consecutively by the first two ATP attempts, the 50-Hz burst, and by a first low-energy shock of 1 J. Finally, one further low-energy shock of 2 J led to successful termination of the atrial tachycardia episode. This example underlines the possibility of a highly specific atrial therapy with the CS lead used. ATP sequences or low-energy shocks enable termination of atrial tachycardias while avoiding higher-energy, ventricular shock therapy. Therefore, they lead to gentler and more comfortable therapies for the patients. As a further result, it is noted that no dislocation of the lead occurred during shock delivery.

Conclusion

The presented results demonstrate that the new coronary sinus lead with its helix structure enables stable

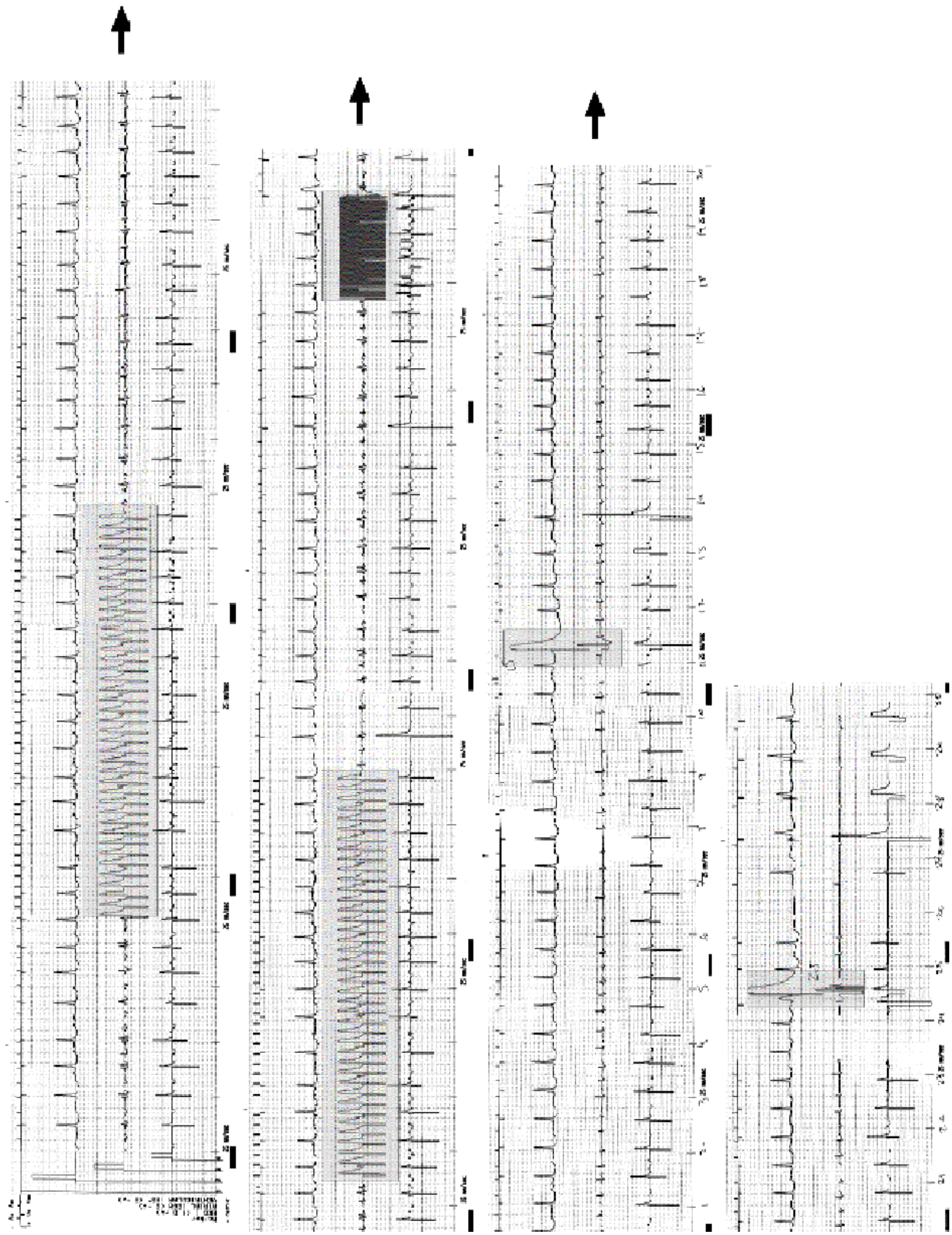

Figure 2. IEGM printout (top line: markers; 2nd line: surface ECG; 3rd line: atrial IEGM; 4th line: ventricular IEGM) showing the course of an automatic atrial therapy delivery via the introduced coronary sinus lead. Different ATP attempts are followed by two low energy defibrillation shocks, of which the second providing 2 J energy was successful to terminate the induced atrial flutter episode.

	electrodes	pacing threshold	pacing impedance
left atrial	dr-pr	1.5 V @ 1 ms	-
	dr-CS coil	1.4 V @ 1 ms	250 ohms
	pr-CS coil	0.8 V @ 1 ms	-
biatrial	RAt/dr(cath.)-RAr(anode)	2.1 V @ 1 ms	216 ohms

Table 1. Survey of the measured left atrial and biatrial pacing parameters of patient 1 using different electrode configurations (terms see text).

	electrodes	pacing threshold	impedance	P-wave duration
left atrial	dr-pr	2.3 V @ 0.5 ms	320 ohms	140 ms
	dr-CS coil	3.3 V @ 0.5 ms	220 ohms	127 ms
	pr-CS coil	1.5 V @ 0.5 ms	222 ohms	140 ms
biatrial	pr-RAr	6 V @ 1 ms	-	70 ms

Table 2. Comparison of measured left atrial and biatrial parameters gained in patient 2. Note the effect of P-wave shortening by the used biatrial pacing lead configuration employing the coronary sinus lead.

positioning in the coronary sinus position during atrial defibrillation. Biatrial pacing resulted in a shortened P-wave duration compared to single atrial pacing, thus enabling a preventive therapy by avoiding intraatrial conduction delays. As part of a global atrial therapy concept, AF and Afl have to be taken into account. Here the new CS lead has proven its capacity since low-energy shocks released from the coil in the CS position enabled successful termination of an atrial flutter episode.

It is now important to investigate the long-term performance of the new CS lead during follow-up. Based on the initial results with the introduced CS lead, we will study its use for ventricular defibrillation. Due to an improved field geometry, defibrillation shocks between the CS shock coil and the coil placed into the right ventricle are assumed to lead to more efficient defibrillation of the left ventricle. In consequence, ventricular defibrillation thresholds are expected to decrease. This would enable the employment of smaller capacitors resulting in smaller devices. Furthermore, battery consumption should decrease, leading to enhanced ICD longevity.

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